TI IMPLANT HOLE QUALITY IMPROVEMENT WITH NEW TOOL DESIGNED

Quanli Han and Dongchen Han

School of Mechanical and Electrical Engineering, Xian Technological University, Xian, China

ABSTRACT

Ti-implant is drilled to get hole in nearly each operation and hole quality took great effect on success of operation .This paper aims at the research of drilling characteristics of through hole on ti-implant, specially the macro-burrs formed after drilling which determined the cost of implant largely. Series experiments were conducted to analysis the effect of processing parameter on formed burr, particularly the axial feed, had a great effect on volume burr. Experiments finds that, the volume of burr at hole entrant is less than that at hole exit, and the burr volume has great effect on workpiece quality and product cost, the burr height formed easily decreases because great attention from scholars and engineers has been paid to, while the burr width size despised naturally plays a great influence on product quality and machining cost. Finally, The new de-burring tool are designed and applied in experiment, the decrease in burr width is obviously found, so the removal of burrs becomes much little than that gotten in traditional tool. The result indicates a promising future of de-burring in practical application.

KEYWORDS

Drilling, Burr, De-Burr, Hole Exit, Hole Entrance.

1. INTRODUCTION

Ti implant has been using in many operations because of its extremely high biocompatibility and cost performance. Ti-implant is drilled to get hole in nearly each operation and hole quality took great effect on success of operation. The undisputable fact is that the macro-burrs formed after drilling determined the cost of implant largely. And the thorny engineering problem, removal of macro-burrs formed after drilling has not been removed, especially on different-machined materials such as Ti with through holes.

Ti classified as difficult-to-machine material shows its special characteristics in thermal conductivity and affinity to tool materials and hardness and strength at high temperatures. As one of the final steps in the fabrication of components, Drilling Ti is very vital for many applications because this has considerable economical concerns and accounts for a large percentage of all machining processes. Up to now many researchers' works have been done by researchers, and several papers related to drilling Ti have been published. Pei reviewed drilling processes for Ti comprehensively to improve the cost-effectiveness of currently-available drilling process and/or to develop cost-effective drilling processes [1]. Dornfeld investigated process conditions and drill geometry during the drilling burr formation in Ti [2]. Cantero studied the evolution of drill wear, quality of machined hole in the dry drilling of alloy Ti6Al4V [3]. Lazoglu estimated the

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temperature evolution of drill in Ti6Al4V drilling under various process conditions [4]. Karagade developed a comprehensive finite element model to evaluate temperature distribution in drilling of Ti considering a variable heat partition model and ploughing forces [5]. Sharif conducted experiments to investigate performance of coated drill when drilling Ti 6Al 4V [6]. Rahim worked on high speed drilling of Ti in the direction of uncoated drill and palm oil as MQL lubricant [7,8]. Pecat brought out chip extraction index to identify suitable cutting parameters and process conditions for drilling Ti6Al4V [9]. To the people's surprise, Ti/others (CFRP , graphite , bismaleimide or Composite) Stack drilling has greatly drawn researchers' attention for their increasing widely application, processing optimization , tool wear and other related topics in drilling process has been seen in literature[10-12].

Expect above mechanical drilling of Ti, researchers brought out some advanced drilling process recently to meet the requirement in productivity and precision of part. Spakal and Plaza carried out work on micro-EDM drilling of Ti6Al4V in the field of optimization of process parameters and creative design of drill respectively [13,14]. Sakurai and Okamura made pioneering work of low frequency vibration drilling of titanium alloy [15,16].Trough-hole drilling quality, specially hole entrance and exit quality take great effect on product assembly feature. Scholars have research on hole entrance and exit defects in aspect of drilling mechanism, drill bit structure, cutting parameters optimization, and so on. And their achievements have promoted drilling technique development greatly. However, drilling defects has inherently resulted from the pushing cutting in semi-enclosed working zone and difficulty of chip removal, and therefore advanced drilling fails to meet the demand of high precision and efficiency hole-making. In-depth study on hole exit features should be made continuously. To analyses hole exit characteristics, we conducted experiments to investigate the effect of processing parameters on hole exit (burr), and then designed a new tool to de-burr for avoiding the increase in the cost of manufacturing.

2. EXPERIMENT SETUP

The block of Ti6Al4V, as workpiece material, was used in this study. A bar of Ti with the diameter of 80mm was cut into 80mm thick disks and slotted to produce an equilateral triangular section with a side length of 20 mm as sown in Figure 1a. Holes of 5.5mm holes were drilled that exit on the centreline of slot. Burrs were observed after hole sectioning using wire EDM at measurement locations labelled A and E in Figure 1b, which represented flat exit surface conditions, and those labelled B , C, D, F, G and H, which represent curved exit condition. Both exit surfaces were examined because exit surface curvature is known to affect burr development and the resulting burr formations.

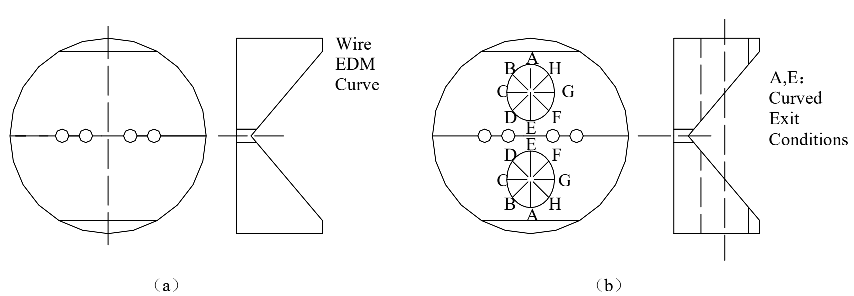


Figure 1. Ti6Al4Vwith (a) EDM Cross-Setting Detail and (b) Burr Measurement Locations

In this study, drilling operations were performed on BJXK5076 five axis high-speed machining centre. As shown in Fig. 2, a Kistler three-direction stationary dynamometer (9257B) and supporting Kislter charge amplifier (type 5070) were used. And to measure a three-direction cutting forces, data acquisition board were utilized as well as Kistler software. In this study, the drillings recommended by tool manufactures were selected for drilling tests. The composition of the cutter matrix is WC8%Co, and the thickness of the TiAIN coating is 1~3μm. The detailed parameters of cutter used in this study are shown in Table 1, the novel fixture designed was used to clamp the workpiece effectively also seen in Fig. 2. And the cutting parameters for drilling Ti6A14V are given in Table 2.

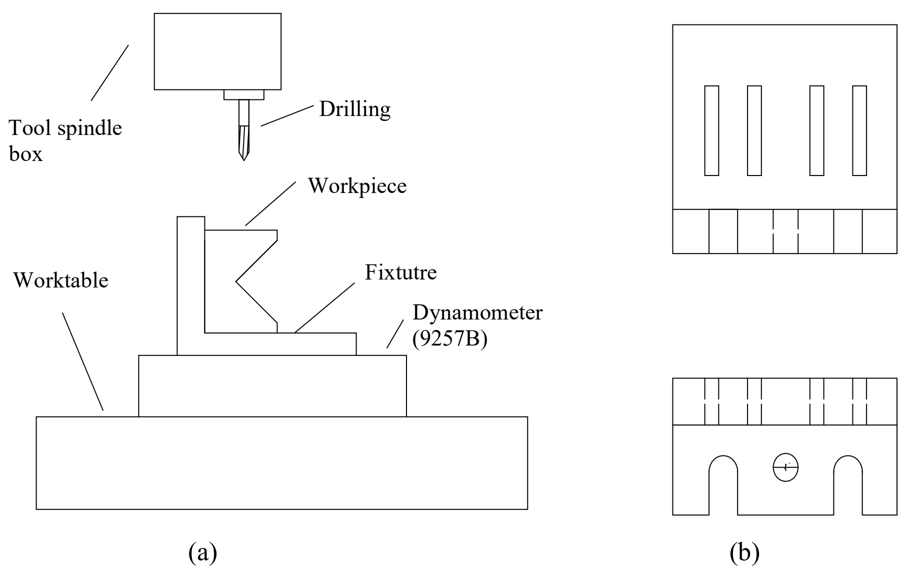


Fig. 2 Schematic of Experiment designed (a) Experimental setup and (b) Fixture

Table 1. main parameters of the drilling

Materials	Top angle	Spiral angle	Transverse edge oblique angle	Transverse edge length(mm)	Tip morphology
Tungsten carbide YG6	118°	25°	66°	0.6	Balance

Table 2. the cutting parameters for drilling Ti6Al4V

Cooling condition	Cutting speed	Axial feed	Hole diameter	Hole depth	Axial distance of tool machined
Water	30,60,70, 110 r/min	0.07,0.08, 0.09,0.10 mm/r	8mm	35mm	50mm

The experiment processes detailed the following steps. During drilling, tool went forward 1.5mm then back 1.0mm, then went forward while stop turning. Because the processing parameters takes great effect on hole exit quality, especially the axial feed. Series experiments with various axial feed were conducted to analysis the effect of processing parameter on formed burr. After drilling, one workpiece was cutting into two halves, in order to investigate the whole structure of hole. The influence of processing parameters to hole exit quality was analyzed by the observation of the geometry of burr with the Hirox KH-1000 optical microscope attached to personal computer. The two directions were used to get the burr height and width, and for each observation the observed points on hole exit was chosen as Fig.1 (b). On each point, the burr height and width were measured on the drawing of through hole of workpiece according to the Fig. 3, and then, the average of measurement result above was obtained to value the formed burr height and width of hole. New de-burring tool was designed to improve hole exit quality. And the designed object in new tool was to decrease plastic deformation at the end of the cutting process, which was seen in Fig. 4. And to validate the function of new designed tool, the comparative experiments of new designed and traditional tool were conducted. To analysis the effect of force on burr formation, the force at the beginning of burr was determined, according to the measurement curve of force from the stationary dynamometer.

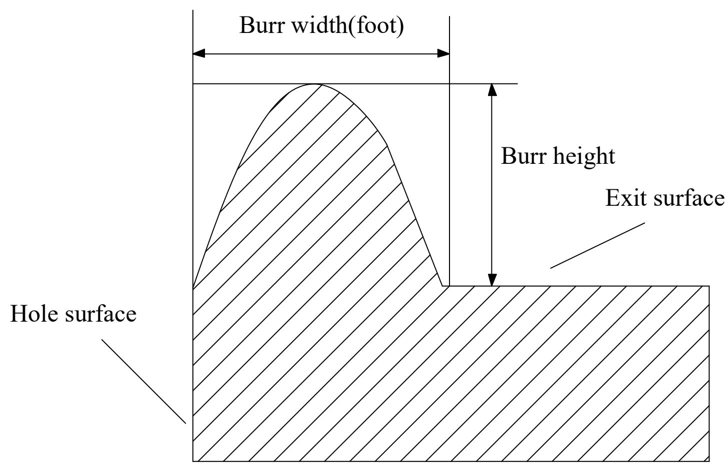


Figure 3. Note how the caption is centered in the column.

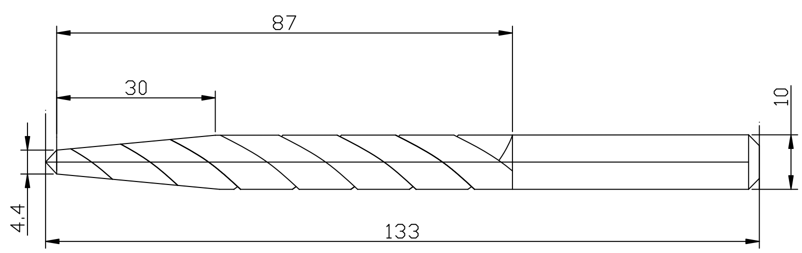


Figure 4. Schematic of tool designed in study

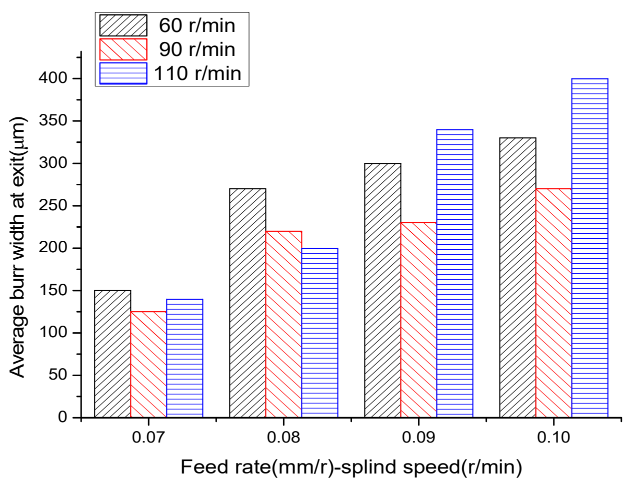
3. Results And Discussions

Fig. 5 and Fig. 6 show the exit burr widths and heights under different spindle speeds and feed rates. Overall, the burr width is larger than burr height when the processing parameters are kept same. The variation of the burr heights ranged between 10μm and 70μm at exit hole, while that of burr width did between125 and 450μm. One noticed point is lack of the value of burr when the processing parameters are the spindle speed of 30 r/min and the feed rates of 0.09 mm/r and 0.10 mm/r. Because the processing condition is the combination of too low spindle speed and tool high feed rates, it is unable to process hole. The machining energy in processing condition above on tool is less than the specific energy of workpiece, the volume of removal material is zero, so the value of burr height and width at exit is zero, as shown in Fig.5 and 6.

When the spindle speed keeps constant, the burr width and height increases with the increase in feed rate. The minimum change of burr width is seen in spindle speed of 90r/m when increasing in feed rate, while that of burr height id done in spindle speed of 60r/m. The change of burr width and height are 145μm and 9μm separately. When the speed rate keeps constant, the burr height

increases with the increase in spindle speed, and the minimum burr width is seen in spindle speed of 90r/m.

The volume of burr determines cost of taking removal materials away from the workpiece. The cross-shape of burr is assumed to be triangle to calculate the volume of de-burring, the volume of burr is determined according to the product of the cross sectional area and hole perimeter. The calculation of de-burring volume with increase in feed rate and spindle speed is seen in Fig.7.



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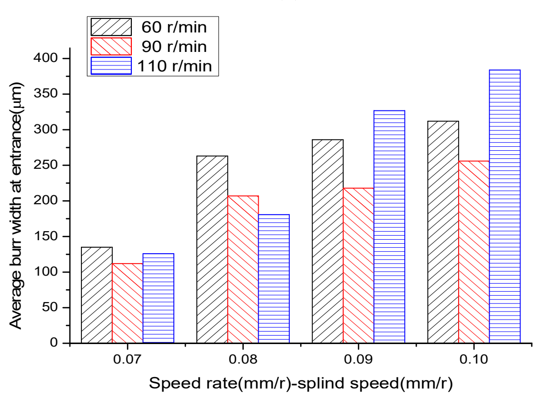
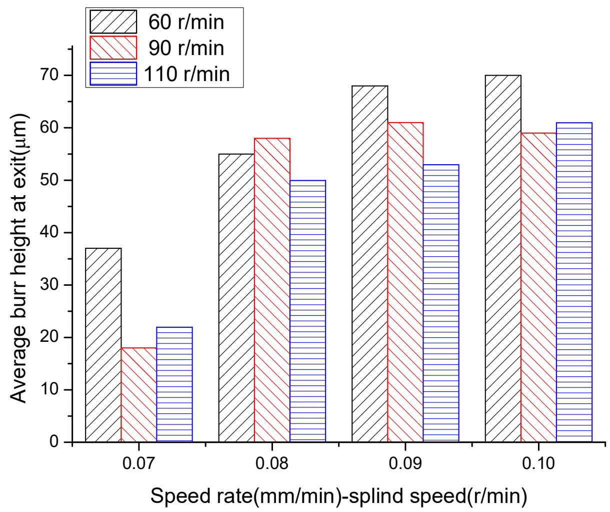


(b)

Figure 5. Average burr width (a) at exit (b) at entrance.



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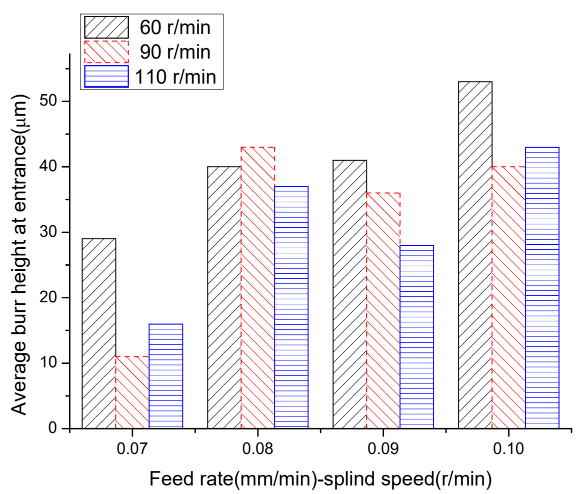
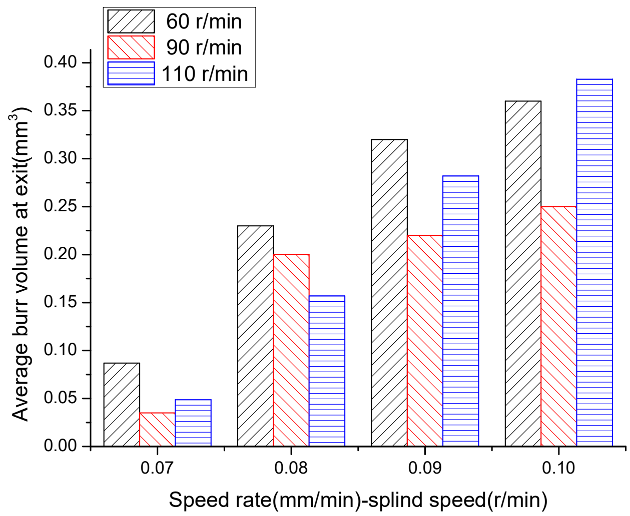


(b)

Figure 6. Average burr height (a) at exit (b) at entrance.

From Fig.7, when the spindle speed keep constant, the burr volume increases with the increase in feed rate, and with the increase in feed rate, the rise by a small margin is seen. When the speed rate keep constant, the burr volume declines and then climbs up with the increase in spindle speed, And the minimum burr volume is commonly seen in spindle speed of 90r/min. The most popular processing parameters is feed rate of 0.08 mm/min when the burr volume and rate of feed rate is the minimum, to be close to 0.21mm^3 and 0.28mm^3 correspondingly at hole exit and entrance. That means the burr volume is the least while the feed rate is the fastest, which brings great helpful result in manufacturing process.



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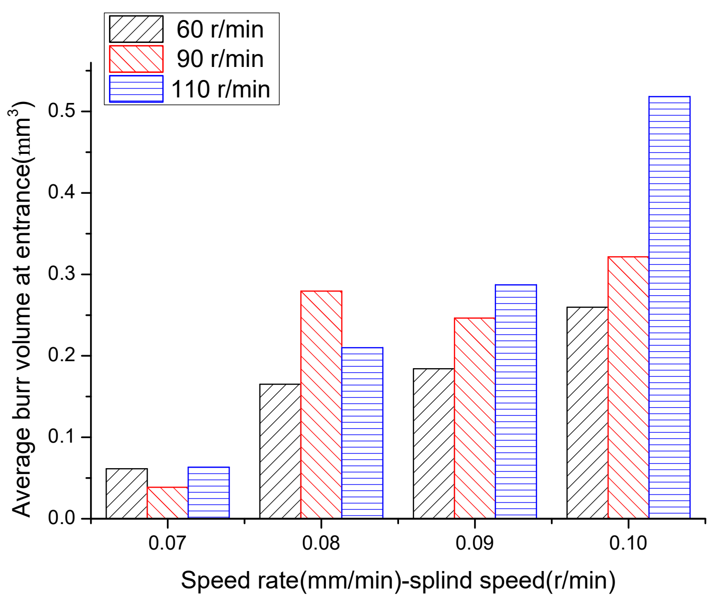
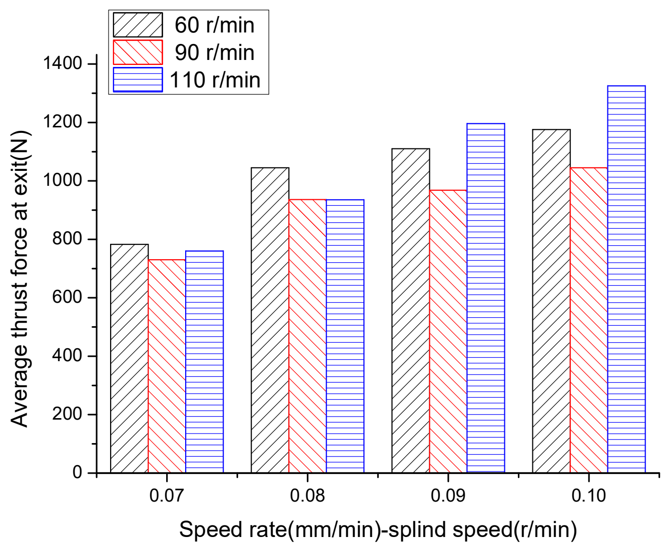


(b)

Figure 7. Average burr volume (a) at exit (b) at entrance.

The thrust forces and torque of tool in drilling with various spindle speed and feed rate were listed in Fig. 8 and Fig.9 respectively.

Overall, the variation of the thrust forces ranged between 730N and 1370N and between 600N and 1250N at exit and entrance correspondingly when drilling, and that of thrust torque did between 258N • mm and 1021N • mm and between 190N and 980N at exit and entrance correspondingly.



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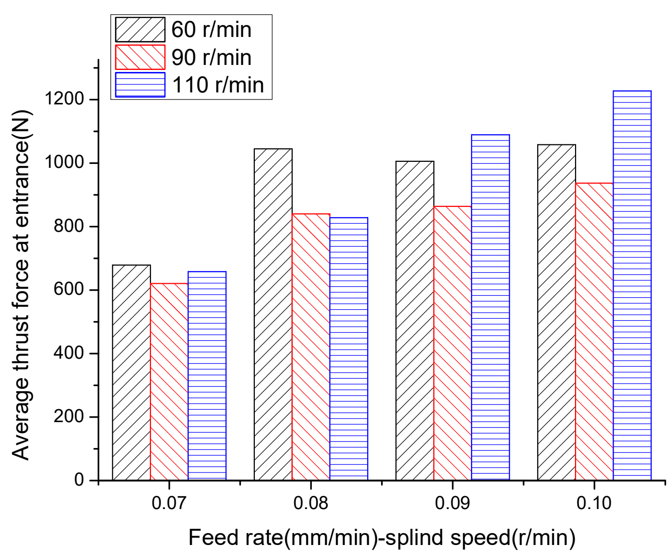

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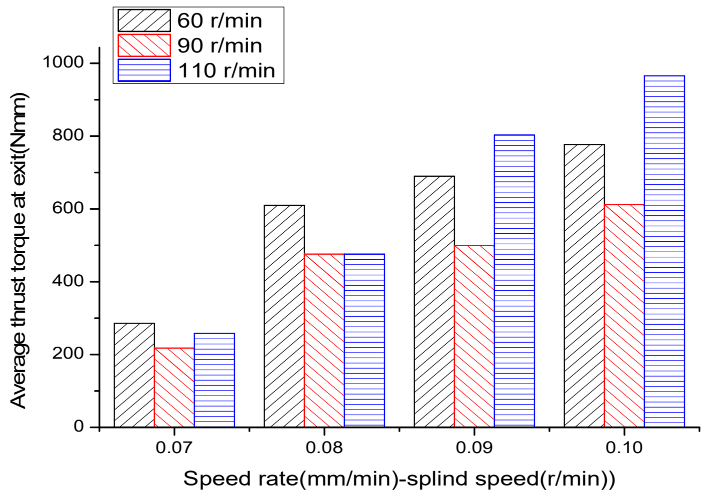
Figure 8. Average thrust force (a) at exit (b) at entrance.

Fig.8 indicted that, the thrust force increases with the increase in feed rate when the spindle speed keeps constant, and the rise by a small margin is seen with the increase in feed rate. When the speed rate keeps constant, the thrust force rises with the increase in spindle speed, and the rise by a small margin is seen with the increase in feed rate.

Similarly in Fig.9, when the spindle speed keep constant, the thrust torque increases with the increase in feed rate, and the small range of increase in torque is found. When the speed rate keep constant, the thrust torque rises with the increase in spindle speed and the rise by a large margin is seen with the increase in feed rate.



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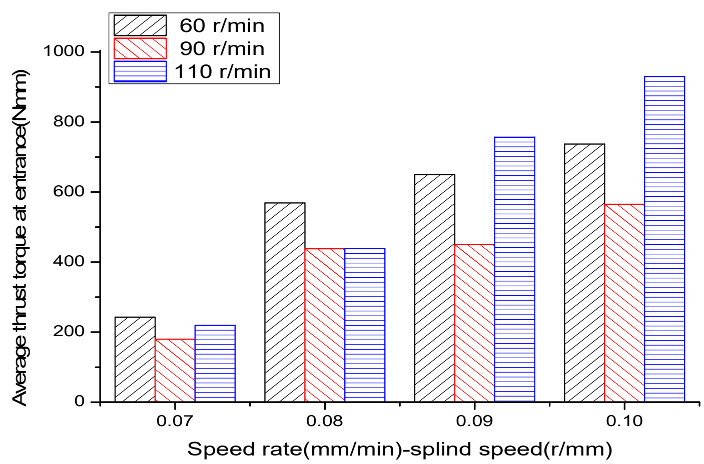


(b)

Figure 9. Average trust torque (a) at exit (b) at entrance

Based on the data from dynamometer and knowledge of cutting principles, Excel 2005 was used to get the experimental formulas for force and torque. The result is followed.

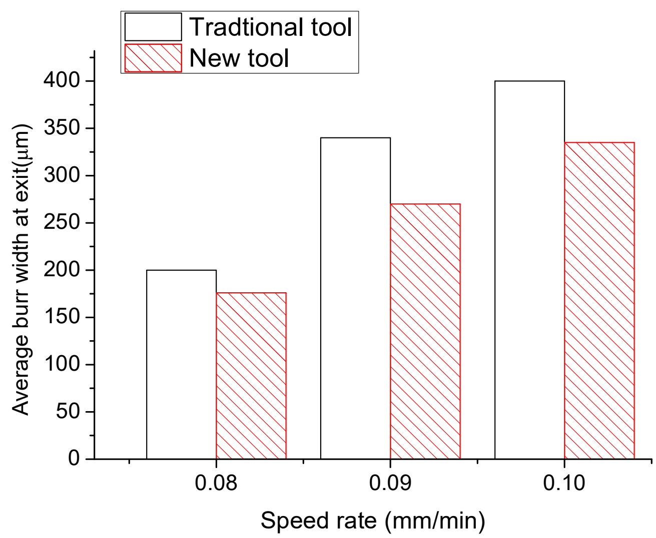
Fz= 1560Df0.74V0.29. (1)

T2= 4.40×10-2D2f1.43 V0.67. (2)

Where, Fz stands for thrust force, whose unit is (N); D stands for drill diameter, whose unit is (mm); f stands for axial feed per revolution, whose unit is (mm); V stands for spindle speed, whose unit is (r • min-1); T stands for thrust torque, whose unit is (N • mm).

The followed findings from those Eq.1 and Eq.2 are gotten. Thrust force and torque increases with the rise of spindle speed and feed rate, whose reason can be analyzed in following words. Firstly, increase in feed rate makes cutting thickness big, so increase cutting force, then thrust force and torque increase; secondly, the spindle speed and feed rate increase feed rate per unit time of drilling, because of low elastic modulus of workpiece, elastic force to axial and pore walls increase, so the thrust force and torque increase. Finally, the strain reinforcement of titanium alloys increases the thrust force and torque under increased feed speed.

To find the method to simple the burring on hole exit and entrance, new de-burring tool was designed. To validate decrease in burr using the new be-burring tool designed, the comparative experiments were conducted and some comparisons were made in terms of burr width, burr height, and burr volume. Based on above experiment, the processing parameter in comparative experiment was followed. The feed rates were chosen from 0.08mm/min and 0.09mm/min and 0.10mm/min, and the spindle speed equates to 60r/min. The comparative experiment's result was shown in Fig.10 and Fig.11 and Fig.12.



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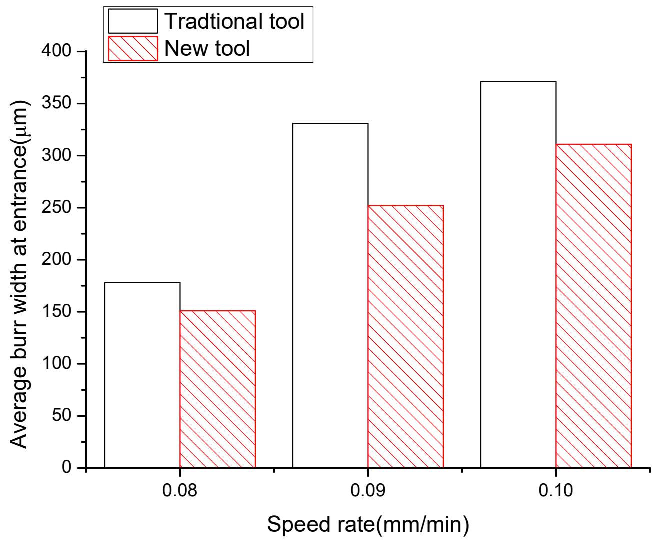

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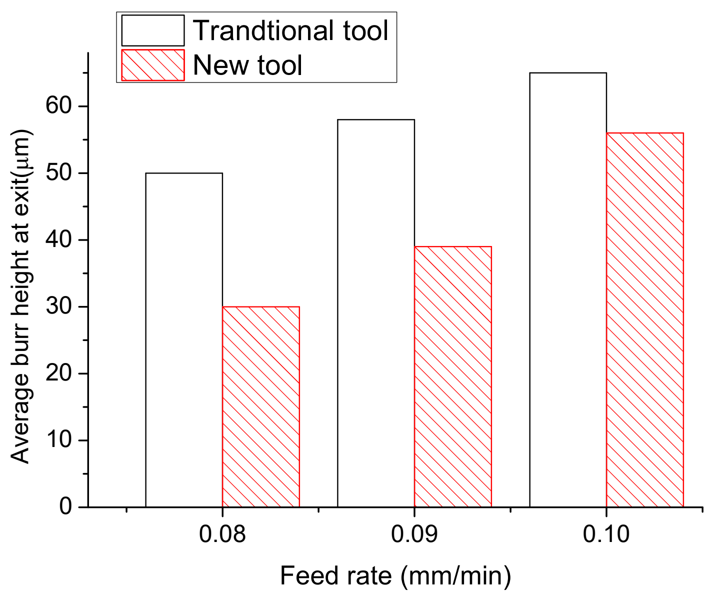
Figure 10. Average burr width when using new tool (a) at exit (b) at entrance.



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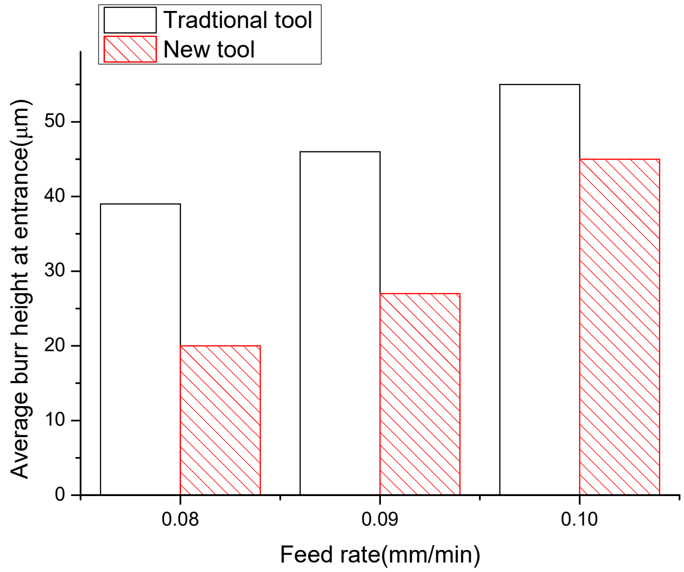


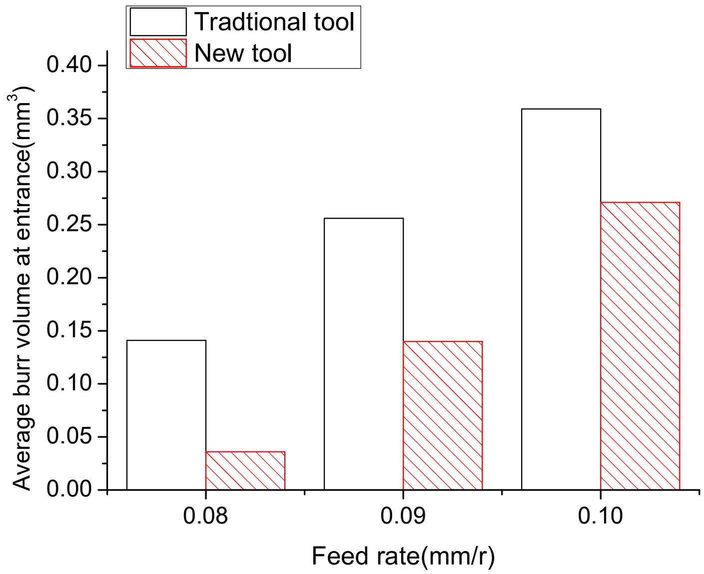
(b)

Figure 11. Average burr height when using new tool (a) at exit (b) at entrance.

Fig. 10 and Fig. 11 respectively show the exit burr widths and heights under different feed rates when using the new and traditional tools. Overall, the variation of the burr heights using new tool ranged between 30µm and 56µm at hole exit and between 22µm and 45µm at hole entrance, while that of traditional tool did between 50µm and 65µm and 39µm and 56µm at hole exit and entrance correspondingly. And the variation of the burr widths using new tool ranged between176µm and 335µm at hole exit and between 150µm and 325µm at exit entrance, while that of traditional tool did between 200µm and 400µm and between 175µm and 376µm at hole exit and entrance correspondingly.

From Fig.10, the exit burr width rate of traditional and new tools is between 1.14 and 1.28, which means the decrease in burr eight used new tool is 16%～27% than that did the traditional tool. Correspondingly the entrance burr width rate of traditional and new tools is between 1.10 and 1.25, which means the decrease in burr eight used new tool is 14%～23% than that did the traditional tool.

From Fig.11, the exit burr height rate of traditional and new tools is between 1.13 and 1.26, which means the decrease in burr eight used new tool is 12～20% than that did the traditional tool. While the entrance burr height rate of traditional and new tools is between 1.16 and 1.29, which means the decrease in burr eight used new tool is 16～28% than that did the traditional tool.



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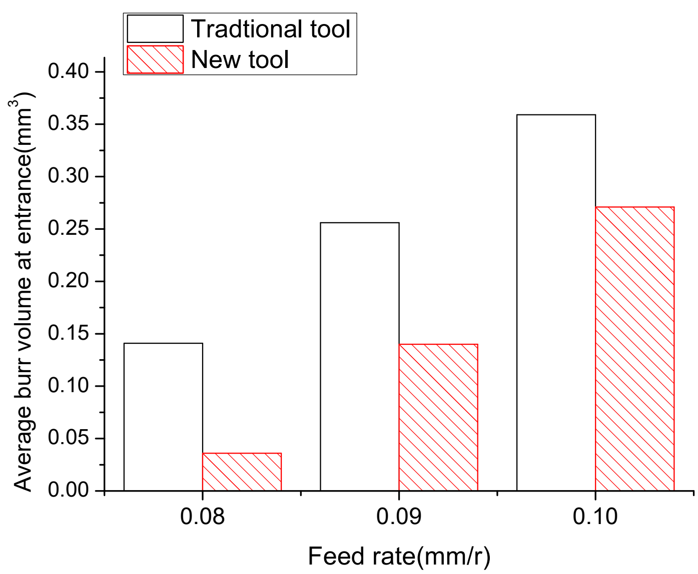

(b)

Figure 12. Average burr volume when using new tool (a) at exit (b) at entrance.

From Fig.12, the exit burr volume rate of traditional and new tools is between 1.3 and 3.2, which means the decrease in burr eight used new tool is 20%～70% than that did the traditional tool. Similarly, the entrance burr volume rate of traditional and new tools is between 1.47 and 3.42, which means the decrease in burr eight used new tool is 23%～76% than that did the traditional tool.

The reason for above phenomena can be explained in following words. Workpiece deformed rate and transportation of chip during the drilling process can be attributed to characteristics of burr at exit. It is commonly thought that burr is the result of workpiece deformation under force and characteristics of workpiece, such as elastic modulus thermal conductivity.

When new tool is used, the exit burr height and width is decreased, and the former is less than the latter, and the entrance is larger than the exit, which leads to the promising results. First of all, the decrease in burr height and width bring out the volume reduction of burr at exit. Last but not least, decrease in burr width is more than that in burr height, which finally reduce time to remove burrs. Those result leads from the plastic deformation rate and accumulation deformation degree.
Either burr height and width or burr volume, the value at entrance was less than that at exit. Because the burr volume was different at entrance and exit, this naturally resulted from the working of material removed.

4. CONCLUSIONS

Series experiments were conducted to investigate hole exit characteristics of Ti6Al4V drilled. Some findings can be gotten.

1) Axial feed rate takes the great effect on burr formation and volume compared to other processing parameters such as spindle speed.
2) Burr width has significant impact on working hours to de-burr hole edge, which determines the burr volume.
3) New designed tool can be used to decrease burr width and height, resulting into reduction of burr volume. And the promising result is to get the more reduction of the burr width than that of burr height, when comparing with use of traditional tool.

Hole exit quality has been one of the most difficult issues in manufacturing field, this work in paper is just the beginning and there are a lot of work to do in following years. Future work would be centered on determining the optical processing parameters to improve quality and reduce de-burring time.

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AUTHORS

Quanli Han was born in Nov. 1972 in Xian. He obtained his B.S. Degree at Xian Mining Institute in China in 1997, and completed his M.S. with Prof. Yushan Xu at Xian Science and Technology Institute in 2001 and got Ph. D at HuaQiao University in 2008 respectively. He joined Xian Technological University in Jan. 2009. His major is Mechanical Engineering. He has been a lecturer since Jan. 2009. Until now, he has published 10+ papers. His current research is focused on the functional surface design and application, precision machining of large ceramic surfaces, etc.

DongChen Han was born in Nov. 1994 in Xianyang. He obtained his B.S. Degree at Zhongbei University in 2016, and has studied at Xian Technological University from Step. 2016. His major field of study is Mechanical Engineering, and his current interest is functional surface design and application.